International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 2, Apr 2020, 625–632

BOOST THE HARDNESS AND TENSILE PROPERTIES OF MILD CARBON STEEL BY SURFACE TREATMENT

Dr. YASER A HADI & ABDULRAHMAN S. SAIT

Department of Mechanical Engineering Technology, Yanbu Industrial College, Saudi Arabia

ABSTRACT

The performance of mild carbon steel was improved slightly by additional alloys, but these incremental changes were not sufficient to maintain the high operating temperatures. This article discusses the surface hardness of mild carbon steel in the local market and the tensile properties. To achieve this objective, carburizing surface treatment is used. Specific carburization temperatures were used for 825 ° C, 850 ° C, 875 ° C and 900 ° C, 3 hours, 6 hours, 9 hours, 12 hours, 18 hours and 24 hours. For the sake of comparison and results analysis, annealing and quenching hardening were performed. The ultimate strength of the tensile can be increased in the light of the combustion conditions based on the current work. The strength of the specimen obtained can be increased by 70% and the hardness can be increased by 108%. The hardness of the hardened specimen can be achieved at carburizing temperatures of 850 ° C and 900 ° C and at 12 hours.

KEYWORDS: Hardening, Carburizing, Annealing & Mild Carbon Steel

Received: Jan 17, 2020; **Accepted:** Feb 07, 2020; **Published**: Mar 20, 2020; Paper Id.: IJMPERDAPR202062

Original Article

INTRODUCTION

The structural composition of steel is linked to its properties; the mechanical characteristics can be determined by the alteration of the dimensions, form and distribution of the various components [1]. Mild carbon steel is an alloy of iron which is produced widely for a variety of applications with a defined carbon range from 0.1 to 0.25% [2]. Due to the excellent ductility and durability of mild carbon steels, different processes of machining can be carried out with less defectors [3]. The surface properties of parts after machinery can be increased and used in engineering applications, such as gear drives, pump shafts and guide rods with the ability to change the strength, corrosion resistance, wear resistance and fatigue resistance of mild carbon steels by hardening or thermocoupled heat treatment. [4,5]. Improving functional characteristics is the most common way of increasing material wear resistance [6]. The standard toughness treatment can be used to meet the high demand for hardness, but this form of heat treatment improves hardness over the entire area of the material treated with heat and is therefore too toughened for this reason. The main purpose of the current work is to increase surface hardening and to preserve the highest possible durability of the material [7]. Various surface hardness techniques such as surface flame treatment and chemical surface treatment have been developed [8]. This study uses the method of combustion to introduce carbon atoms to the matter's surface. The carbon atomic atoms that scatter across the specimen surface are formed by a combination of carbon, sodium carbonate and calcium carbonate. Temperatures and keep times were different for the specimens.

EXPERIMENTAL PROGRAM

The carburized specimens were tested with a tensile and hardness testing machine for the mechanical properties of the tested steel to assess the effect of the carbricating process. In order to relieve internal tension and minimize the specimen homogenization, only a handful of specimens underwent a rectifying and water quenching process before carrying out the carburizing procedure. In order to interpret and compare the results of carburized specimen experiments, the behavior of hardened specimens shall also be applied.

Mechanical Properties

Steel yield strength ranged from around 300 MPa to over 1700 MPa, with the tensile strength ranging from 450 to 2350 MPa. Table 1, table 2 and table 3 display the tensile characteristics of the raw material when collected, rinsed, and hardened specimens as indicated.

Table 1: Tensile Properties of Raw Material

UTS (N/mm^2)	$б_{p0.2}$ (N/mm^2)	$б_f$ (N/mm^2)	Toughness (N.m)	Ductility (%)
738.89	491.07	518.83	228.91	15.23

Table 2: Tensile Properties of Annealed Material

UTS (N/mm^2)	$б_{p0.2}$ (N/mm^2)	$б_f$ (N/mm^2)	Toughness (N.m)	Ductility (%)
597.23	410.62	445.61	317.85	24.81

Table 3: Tensile Properties of Water Quenching Hardened Material

UTS (N/mm^2)	$б_{p0.2}$ (N/mm^2)	$б_f$ (N/mm^2)	Toughness (N.m)	Ductility (%)
1065.79	864.86	1065.79	14.06	0.92

Due to the significance of the carbon content assessment, the following empirical formula was used for the determination of the carbon content of the steel under consideration:

$$UTS=700\alpha+250 \quad (1)$$

Where UTS is the ultimate tensile strength in N/mm^2 and α represents the carbon content (%C) of the tested steel. [9] offered expressions relating hardness and tensile strength in the form of

$$TS = (H/2.9)\,(n/0.217)^n \quad (2)$$

where TS is tensile strength, H is hardness n is the strain-hardening exponent.

Brinell Hardness HB (187.5/2.5) method used the universal hardness testing system to measure the hardness of the test specimens. Five readings and the average values for the results analysis have been reported. The treatment temperature (critical temperature) has been calculated using the iron-iron carbide phase diagram and by understanding the carbon content.

Carburizing Process

The purpose of the carburizing process is that the carbon atoms disperse the surface of the specimen thoroughly so that the penetrated carbon layer of the tested sample increases its hardness [10]. A charcoal mix (80%), Na2CO3 (10%) and CaCO3 (10%) calcium carbonate mix (10%) were developed. A combination was developed. In the prepared mixture, the

specimen is packaged and screened into cylindrically displayed containers by a stainless steel disc and a modeling medium within Figure 1. Different temperatures from 825 ° C to 900 ° C with a holding time from 3 hours to 24 hours were applied in order to study the effect on the carburization of the treatment effects, since the diffusion process depends mainly on the temperature and the holding period.

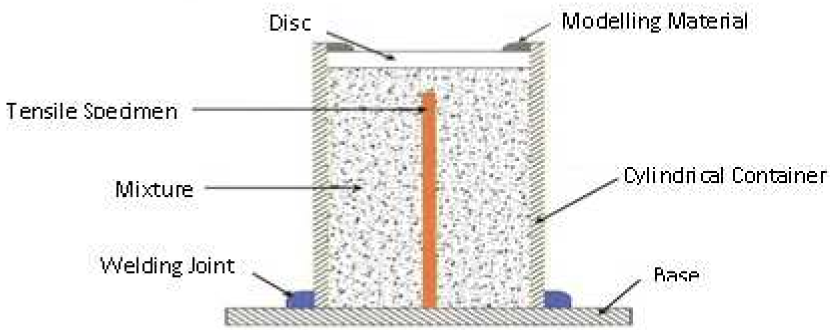


Figure 1: Schematic Representation of the Packed Specimen.

RESULTS AND DISCUSSIONS

Tensile Properties of Heat Treated Specimens

The variations in mechanical properties with different treatment conditions are shown in Figures 2-7. The UTS for carburized specimens at a 3-hour hold time and temperature, 825°C, 850°C, 875°C and 900°C were given in addition to the collected and hardened specimens, in the Bar Diagram shown in the Figure 2. It is clear that the UTS is close to each other in carburized conditions while the UTS of hardened specimens is relatively high. In comparison with the carbusted specimen, the gap in the proof of stress ($бp_{0.2}$) in hard specimen as shown in Figure 3 is very high. Figure 4 indicates the ductility of the different therapy settings, with a very low ductility (0.92%) of harded specimen and a ductility of 15.23% as receipted. The combustion cycle closely follows the ductility of the measured material, in particular at 850°C. For a strain at the ultimate stress as given in figure 5, the same pattern of ductility dependence on the heat treatment is observed. The maximum stress fracture is reached for 3 hours of carburizing time at the temperature of the 850°C carburization, as shown in figure 6. Figure 7 shows that the carburizing state of 850°C and 3 hours is about equal to and higher than the toughening of the annealed specimen and thus can explain the final intent of the current work.

Tensile Properties at Different Carburizing Conditions

In general, the UTS is reduced for various combustion temperatures to 6-9 hours, and the time is increased to 12 hours. In addition, after 12 hours, the UTS is constant in the same way as in 850 ° C, as shown in Figure 8. The variation in evidence of stress in time of carburization is shown in Figure 9. Clearly, with carburizing time, the stress of evidence increases. Figure 10 shows the reliance on ductility on carburizing time. The carburizer specimen's ductility decreases significantly with the carburizer until it lasts 9 hours. Generally, specimens with lowest ductilities of 1.39% at 850°C and 24 hours above hard specimens with ductilities of 0.92% are still hardened. As is well known toughness for the carburized specimen is an important parameter; a relationship is therefore provided between toughness in the specimen and the time of carburization in Figure 11. The toughness of carburized specimens is reduced by up to 9 hours and is constant after 9 hours. In fact, the toughness of the lowest carburized specimes is still higher than that of hard specimens. Figure12 shows the percentage changes in toughness of carburized conditions with respect to hardened specimens. Clearly, carburized

specimens are of the lowest strength at 850 ° C and 24 hours, and are by 49.57 percent even stronger than hardened specimens.

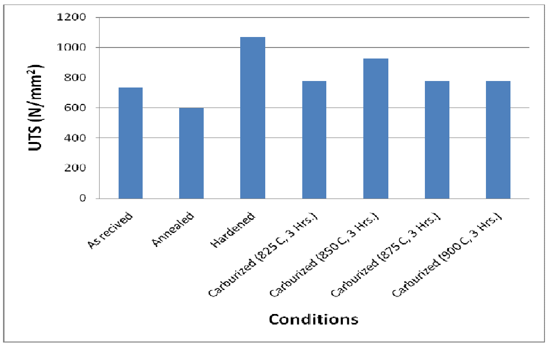


Figure 2: Ultimate Tensile Strength for Different Heat Treatment Conditions.

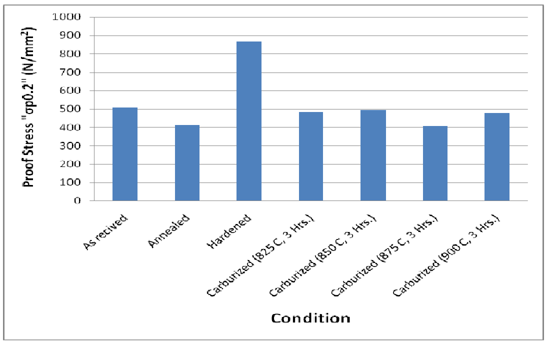


Figure 3: Proof Stress for Different Heat Treatment Conditions.

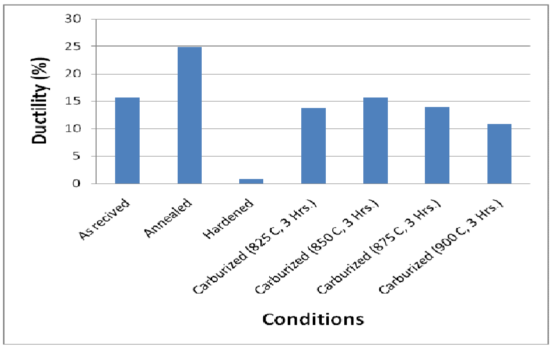


Figure 4: Ductility (Fracture Strain) for Different Heat Treatment Conditions.

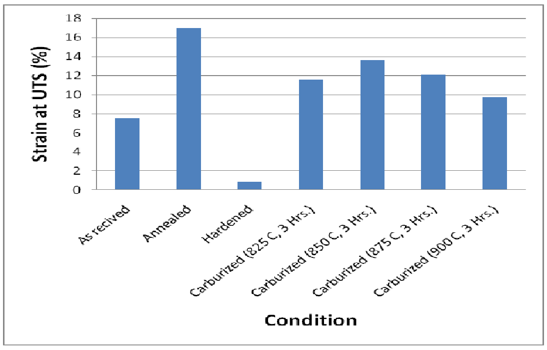


Figure 5: Strain At UTS For Different Heat Treatment Conditions.

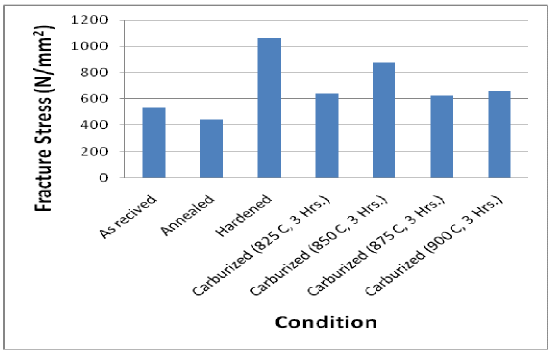


Figure 6: Fracture Stress For Different Heat Treatment Conditions

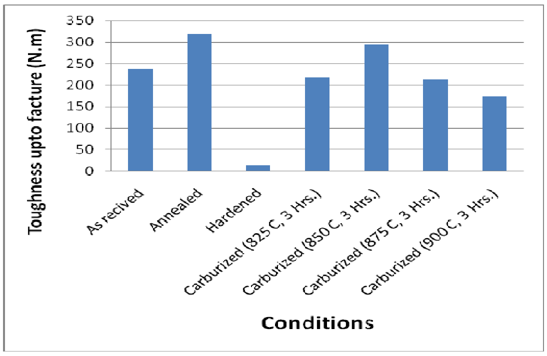


Figure 7: Toughness Up To Fracture For Different Heat Treatment Conditions

Hardness of Different Heat Treatment Conditions

The hardness increases with the time of carburization for various combustion temperatures in Figure 13. After 12 hours of carburizing time, the hardness is almost constant as can be seen in the case of a carburizing temperature of 850°C. The hardness of the carburizing condition of 900 ° C and 12 hours is equivalent to hardness for hardened specimens, and durability of 850 ° C is equal to that of hardened specimen, and hold time 12 hours, 18 hours and 24 hours. The maximum improvement of hardness in Brinell is 70%, as shown in Figure 14, at 12 hours carburizing time, by 900°C and 850°C. Figure 15 shows the percentage of Brinell hardness improvement of carburized specimens compared to the rinsed specimen. The average durability gain of 108% in comparison to the annealed specimen is noted at 850°C and 900°C during 12 hours of carbricating period.

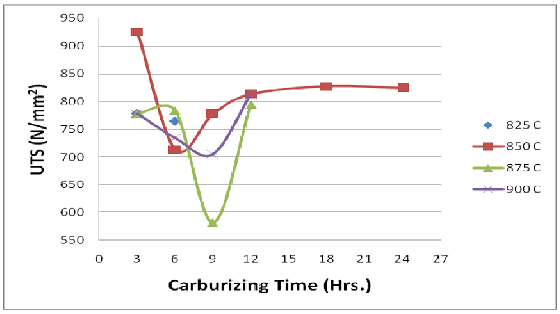


Figure 8: Dependence of UTS for Different Carburizing Temperatures on Carburizing Time

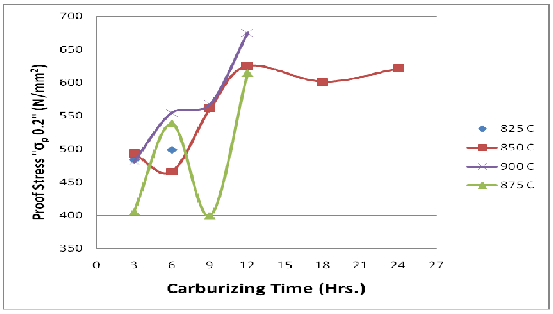


Figure 9: Effect of Carburizing time on proof Stress for different Temperatures

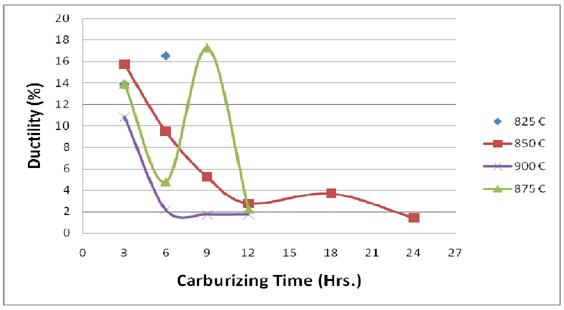


Figure 10: Carburizing Time Variation of Ductility for Different Conditions

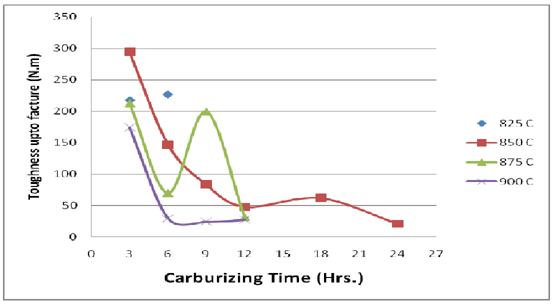


Figure 11: Effect of Carburizing Time on Toughness up to Fracture for different Carburizing Conditions

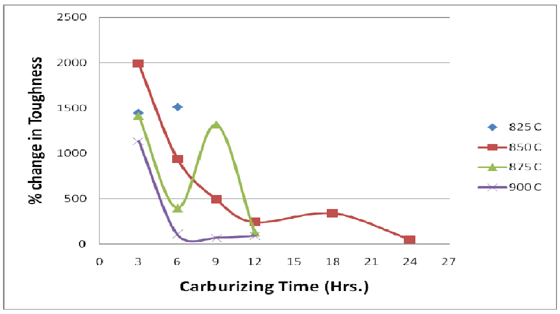


Figure 12: Percentage Changes in Toughness for Different Carburizing Condition Relative to Hardened

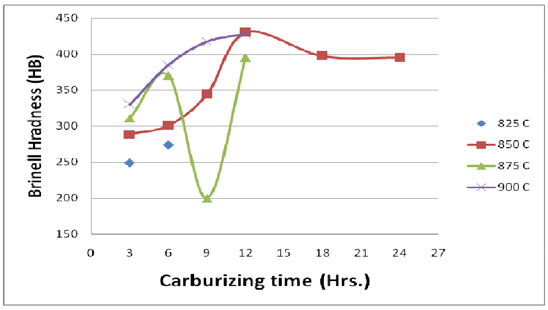


Figure 13: Variation of HB With Carburizing Time

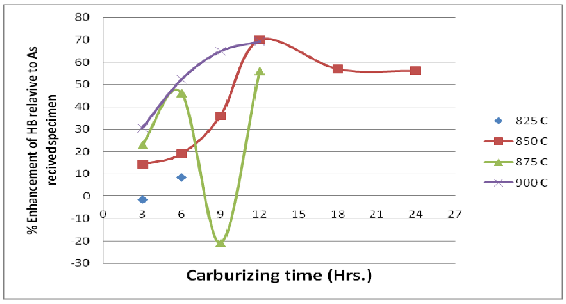


Figure 14: Conditions Relative to as Received Specimen

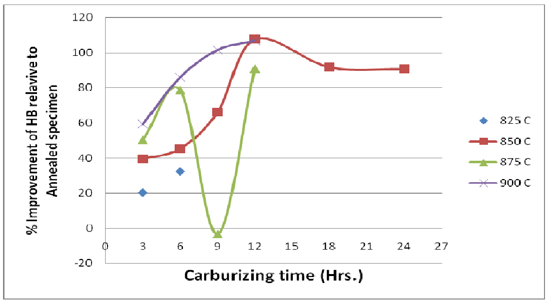
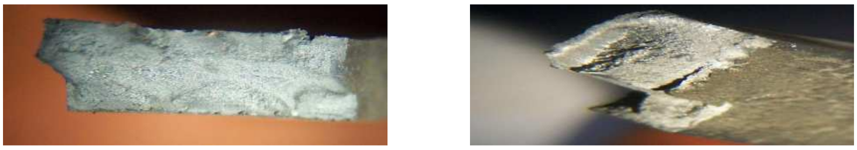


Figure 15: Conditions Relative to Annealed Specimen

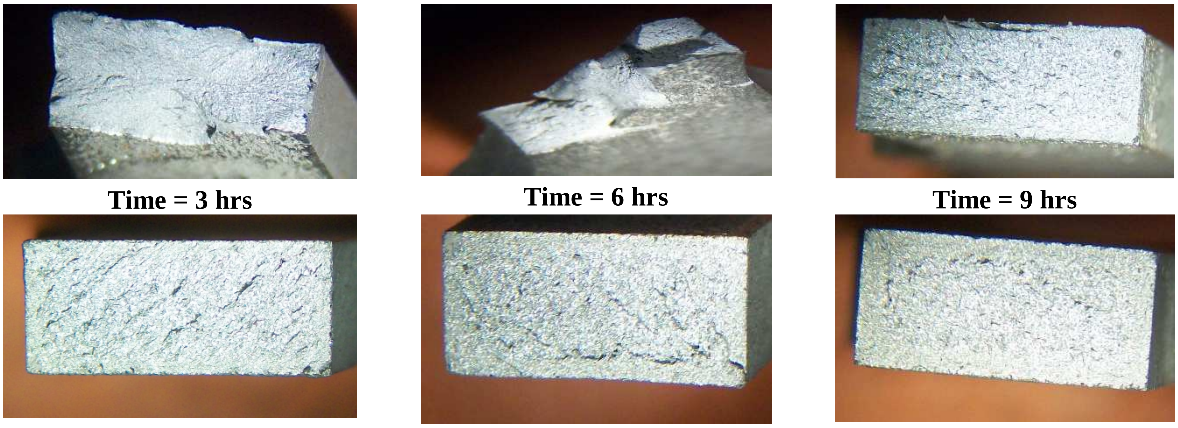
Fracture Surfaces of Carburized Specimens

Figures 16 to figure 19 show the tensile fracture surfaces of carburized specimens. This analysis will, indeed, be the focus of future work on the analysis of the fracture surface needs the Scanning Electron Microscope (SEM).



Time = 3 hrs **Time = 6 hrs**

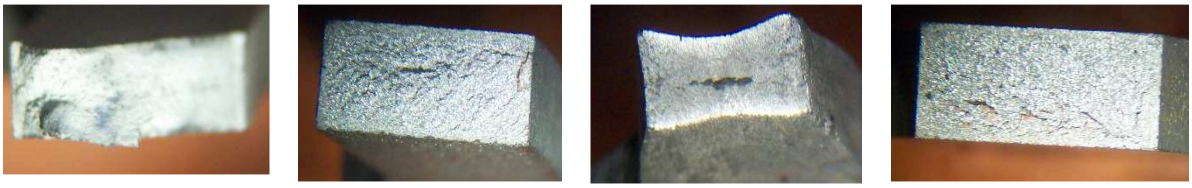
Figure 16: Fracture Surfaces of Carburized Specimens at 825 ^{O}C (7X)



Time = 3 hrs **Time = 6 hrs** **Time = 9 hrs**

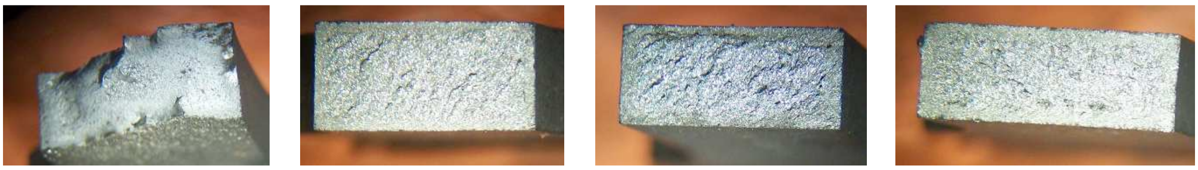
Time = 12 hrs **Time = 18 hrs** **Time = 24 hrs**

Figure 17: Fracture Surfaces of Carburized Specimens at 850^{o}C



Time = 3 hrs **Time = 6 hrs** **Time = 9 hrs** **Time = 12 hrs**

Figure 18: Fracture Surfaces of Carburized Specimens at 875^{o}C



Time = 3 hrs **Time = 6 hrs** **Time = 9 hrs** **Time = 12 hrs**

Figure 19: Fracture Surfaces of Carburized Specimens at 900^{o}C

CONCLUSIONS

On the basis of this study, the following conclusions were drawn:

- The carburization state is better than the reception specimen and nearly equal to the hardness of the annealed specimen. It is of the impact resistance (toughness) at 850 ° C and three hours.
- The UTS increases over 9 hours after carburizing and after 12 hours, the lowest ductility of carburized specimens is greater than the ductility of hardened specimens.

- The hardness of the annealed material can be improved by 70% and 80% with 850oC, 900oC and 12 hold times, respectively.
- The least resistance to effect of carburized specimens is 49.57% greater than the toughness of hardened specimens.

REFRENCES

1. *Donald R. Askeland, Pradeep P. Dulay, & Wendelin J. Wright. (2006). The Science and Engineering of Materials", Sixth Edition, Cengage Learning.*
2. *Hasan MF. (2016). Analysis of Mechanical Behavior and Microstructural Characteristics Change of ASTM A-36 Steel Applying Various Heat Treatment. Journal of Material Science & Engineering, 5, 2.*
3. *Adamu Y; Adamu AA, Salihu Z, & Musa AB. (2019). Evaluation of Combined Heat Treatment Techniques of Testing Hardness and Tensile Strength of Mild Carbon Steel commonly used in Nigeria. J. Appl. Sci. Environ. Manage, 23, 3, 557-562.*
4. *C. Kanchanomai, &and W. Limtrakarn. (2008). Effect of Residual Stress on Fatigue Failure of Carbonitrided Low-Carbon Steel. Journal of Materials Engineering and Performance, 17, 879–887.*
5. *Miran Mozeti. (2019). Surface Modification to Improve Properties of Materials. Materials, MDPI. 12, 441, 1-8.*
6. *Rumana Hossain, Farshid Pahlevani, & Veena Sahajwalla. (2020). Revealing the mechanism of extraordinary hardness without compensating the toughness in a low alloyed high carbon steel. Nature Research, 10, 181.*
7. *A. K. Yadav, N. Arora, & D. K. Dwivedi. (2006). On microstructure, hardness and wear behavior of flame sprayed Co base alloy coating deposited on mild steel. Surface Engineering, 22, 5, 331-336.*
8. *E. J. Pavlina, & Chester Vantyne. (2006). Correlation of Yield Strength and Tensile Strength with Hardness for Steels. Journal of Materials Engineering and Performance, 17, 6, 888-893.*
9. *Abbas Razavykia, Cristiana Delprete, & Paolo Baldissera. (2019). Correlation between Microstructural Alteration, Mechanical Properties and Manufacturability after Cryogenic Treatment: A Review. materials, MDPI, 12, 20, 3302.*